PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN -XV. THE PLANKTON OF YOSA-NAIKAI AND KUMIHAMA BAY, ENCLOSED BAYS ON THE JAPAN SEA COAST-

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PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

XV. THE PLANKTON OF YOSA-NAIKAI AND KUMIHAMA BAY, ENCLOSED BAYS ON THE JAPAN SEA COAST[1]

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With 2 Text-figures and 4 Tables

CONTENTS

Page
INTRODUCTION 151
YOSA-NAIKAI 153
General hydrological conditions 153
Plankton community 153
The plankton on June 4, 1945
The plankton on November 25, 1945
The plankton on April 4, 1946
The plankton on April 20, 1946
The plankton on November 1, 1946
The plankton on June 20, 1947
The plankton on March 19, 1948
Vertical distribution of zooplankton on November 1, 1946
Vertical distribution of zooplankton on June 20, 1947
General consideration and conclusion 156
KUMIHAMA BAY 158
General hydrological conditions 158
Plankton community 158
The plankton on June 22, 1947
Vertical distribution of zooplankton on June 22, 1947
Conclusion 159
REFERENCES 160
TABLES (1–4) 161

INTRODUCTION

With the purpose of studying the productivity of the waters and marine organisms in relation to the topographical and hydrological features, a series of surveys of two enclosed bays, i.e. Kumihama Bay and Yosa-Naikai both situated on the Japan Sea

1) Contributions from the Seto Marine Biological Laboratory, No. 245.

coast of Kyoto Prefecture were projected by Prof. Dr. D. MIYADI *et al.* Of these surveys, the hydrological, benthic studies and that of the shell-deposits have already been published (MIYADI, HABE and YAMAZI, 1950; MAÉDA, 1952, 1953, a and b). And here the present paper deals with the plankton samples obtained during these surveys. The samples were collected at each station by a horizontal and vertical haul of a

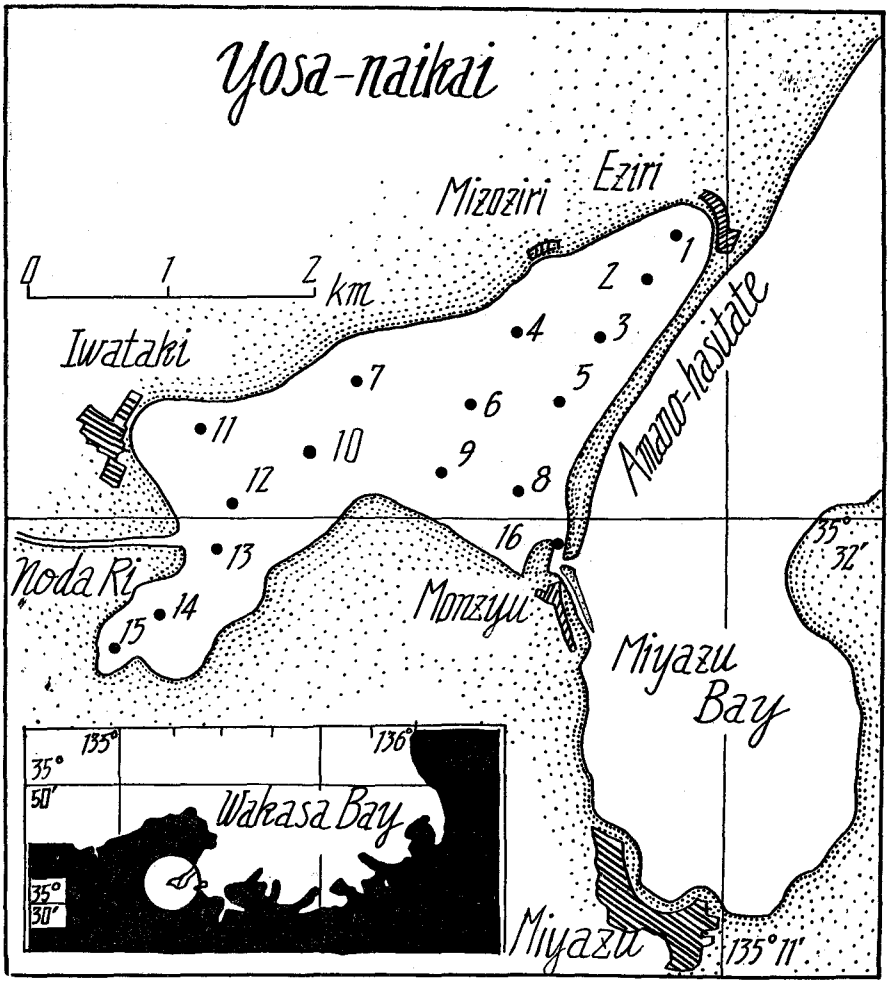

Fig. 1. Map of Yosa-Naikai showing the stations.

net or by taking a liter of sea water using a NANSEN reserving water bottle at each sampling layer. The data of the plankton were discussed in the percentage composition and the total number of plankton per 10 liters of sea water. The materials of Yosa-Naikai were collected at the following stations on the following dates (Fig. 1):

(1) June 4, 1945 (Sts. 1, 6, 8, 10 and 14)

(2) November 25, 1945 (Sts. 5, 6, 7, 9, 12 and 14)
(3) April 4, 1946 (Sts. 6, 6–8, 8 and near channel)
(4) April 20, 1946 (Sts. 2, 8, 10 and 12–13)
(5) November 1, 1946 (Sts. 3, 6 and 12)
(6) June 20, 1947 (14 definite stations)
(7) March 19, 1948 (16 definite stations)

In Kumihama Bay, however, the survey was carried out only once on June 22, 1947 at 24 stations (Fig. 2).

YOSA-NAIKAI

General Hydrological Conditions

Yosa-Naikai is a lagoon of about 5.18 sq. km, separated from Miyazu Bay by a sandbar "Amano-hasidate". The western region near the estuary of the river Noda is relatively shallow measuring less than 10 m in depth, while the eastern region is deeper, being about 13 m in the maximum depth. The water of this lagoon is connected with that of Miyazu Bay by two narrow and shallow channels at the south-eastern corner. This topography and at the same time the shallowness of the tidal amplitude in Japan Sea prevent the active inflow of Miyazu Bay water which is characterized by higher salinity, transparency and dissolved oxygen content and lower silicate and phosphate contents than in the lagoon. Thus, the lagoon water is highly stagnated; the salinity in upper layers is quite low, although it scarcely differs from that of the inner part water of Miyazu Bay (YOSIMURA, 1938; MIYADI *et al.* 1947, 1949, 1952; TATIBANA, 1952; MAÉDA, 1953). The lower strata of the lagoon are so stable that the oxygen content is very small there or quite absent, and in the latter case a considerable amount of hydrogen sulphide is produced there and seals the lower limit for planktonic and benthonic organisms. Thus, the azoic zone appeared in the lower strata (MIYADI *et al.* 1947, 1949).

Plankton Community

The Plankton on June 4, 1945 (Table 1)

Zooplankton occupied the most part of the plankton in the lagoon. Copepods were represented only by dominant *Oithona nana* and a small number of *Acartia clausi* and *A. spinicanda*. *Oithona nana* showed the highest percentage (60–75%) at each station, *Acartia* was distributed similarly, but less abundant (8–20%). Other animals such as *Sagitta crassa* f. *naikaiensis*, *Oikopleura dioica*, *Evadne nordmanni*, *Favella campanula* and *Noctiluca* etc. were very few throughout the stations. Copepod nauplii were numerous (6–15%), Polychaete larvae (2–5%) and pelecypod veligers (2–7%) occurred also, but in lower percentage. Although these animals and larvae

were recorded merely in small percentage, their appearance in the lagoon in relation to hydrological features seems to be very important ecologically.

The Plankton on November 25, 1945 (Table 1)

Important components of plankton were *Oithona nana* (15–80%), *Acartia clausi* and *A. spinicauda* (13–17%), copepod nauplii (5–15%) and pelecypod veligers (5–8%) as in samples of June. Polychaete larvae, *Sagitta*, *Oikopleura* and *Evadne* etc. were not found at all.

The Plankton on April 4, 1946 (Table 1)

Main components were nearly the same as in the previous surveys, except for that several tintinnids occurred considerably; namely *Tintinnopsis cylindrica* (3–4%), *Tin. radix* (less than 1%), *Tintinnus lusus-undae* var. *tenuis* (1–2%) and *Favella campanula* (1–3%) were widely distributed in the lagoon. *Evadne nordmanni* and *Podon* sp. were also recorded at Sts. 6 and 8 in low percentage.

The Plankton on April 20, 1946 (Table 1)

This time *Oikopleura dioica*, *Podon*, pelecypod and gastropod veligers and tintinnids excepting *Tintinnus lusus-undae* var. *tenuis* were not found in the samples.

The Plankton on November 1, 1946 (Table 1)

The samples were hauled horizontally at 3 stations and vertically at several layers at each station. The dominant species in samples were almost the same as in previous investigations, although they were found in quite different composition. The most remarkable phenomenon was the large population of *Dictyocha fibula*, the maximum density of which reached more than 50 thousands per 10 liters, occurring about 95% of total zooplankton. *Oithona nana* (about 0.2%) and *Acartia* (0.1–0.2%) were very few. Tintinnids comprising *Tintinnus lusus-undae* var. *tenuis*, *Tintinnopsis radix* plus *Tin. cylindrus*, *Favella campanula* were relatively abundant, namely 1.3–2%, 1.5–1.4% and less than 0.1% respectively. *Evadne*, *Penilia* sp. and *Oikopleura dioica* occurred also sparsely.

The Plankton on June 20, 1947 (Table 1)

This time the samples were collected horizontally at 16 stations and vertically at 4 stations (Table 2). The zooplankton was richer in the inner part of Iwataki inlet (Sts. 7, 10, 13, 14; 25,000–28,000 per 10 liters) than in Eziri inlet (Sts. 2, 3 and 4; 1,500–10,000 per 10 liters) and the area near Monzyu (Sts. 8, 6 and 9; 1,480–12,000 per 10 liters). The important components of zooplankton were copepods (30–90%), tintinnids (0.1–5%), larval forms (7–90%) and other animals (less than 0.5%). The representatives of copepods were *Oithona nana* (less than 10,000 per 10 liter, less than

40% in Eziri inlet, and 700–3,000, 20–40% near Monzyu) and *Acartia* (less than 150; less than 5%). *Tintinnopsis radix* and *T. cylindrica* were widely distributed, but in a small number. Copepod nauplii and copepodids were generally the most abundant plankters throughout the stations and always occurred in high percentage in zooplankton. Polychaete larvae occurred sparsely. The phytoplankton was little in quantity and distributed rather unevenly.

The Plankton on March 19, 1948 (Table 1)

The plankton was collected at 14 stations. It was a rich copepod plus tintinnid community and consisted of 5–35% of copepods and 30–85% tintinnids. Of these animals the following were the predominant members: *Oithona nana* (2–32%), *Acartia* (1–16%), *Centropages* (0–5%), *Paracalanus parvus* (0–10%), *Tintinnopsis cylindrica* (8–59%) and *T. radix* (0–4%), *Tintinnus lusus-undae* var. *tenuis* (1–42%), *Helicostomella longa* (3–31%) and *Favella campanula* (less than 4%). *Acartia clausi* was more abundant than *Oithona nana* at nearly all stations in this spring season. *Paracalanus parvus* was found only near Monzyu (Sts. 6, 8, 9 and in the channels) and considered to be brought into the lagoon from Miyazu Bay. Tintinnids occurred widely throughout the stations. Larval forms were represented by copepod nauplii (2–20%), polychaete larvae (1–20%) and a small number of pelecypod veligers.

Vertical Distribution of Zooplankton on November 1, 1946

The samples were collected vertically at Sts. 3, 6 and 12 during the day time. The distribution of important zooplankton is shown in Table 2.

Oithona nana distributed from the surface to the 6 m layer. Its number increased at first with depth, and attained to the minimum near the 5–6 m layer at Sts. 3 and 6. Beneath the maximum layer it then decreased with depth and disappeared at the 9 m layer at St. 3, the 12 m layer at St. 6 and 11 m layer at St. 12. The distribution of *Acartia* showed the same tendency, although the population was relatively small. The lower limit of the distribution of polychaete larvae lied at the same depth as in the case of copepods. The larvae were, however, condensed most densely at the 7 m layer at St. 3, the 6 m layer at St. 6 and the 10 m layer at St. 12, where *Oithona* and *Acartia* already passed the maximum layer and decreased to a small number. An enormous quantity of tintinnids, such as *Tintinnopsis cylindrica*, *Tintinnus lusus-undae* var. *tenuis*, *Favella campanula*, distributed densely in the superficial layer, but decreased gradually with depth and disappeared at three stations at the 9, 12 and 11 m layers respectively. Thus the lower limit of plankton distribution was determined clearly.

Vertical Distribution of Zooplankton on June 20, 1947 (Table 2)

The plankton was vertically hauled at Sts. 2, 6, 8 and 12 during the day time.

The quantitative distribution of prominent species of plankton are shown in Table 2. The maximum number of adult females of *Oithona nana*, as well as male, was found at the 6 m layer at St. 2, between 4–8 m layers at St. 6, 8 and 12. Copepodid and nauplii of *Oithona nana* were found abundantly at the same layers as in adult forms at each station, although a small number of individuals were found also at the 0–2 m and 9–10 m layers. Both adult and larval forms were hardly found from the lower layers beneath the depth mentioned above. *Sagitta crassa* f. *naikaiensis* and *Oikopleura dioica* appeared only in a small number between 1–6 m layers at Sts. 2, 6 and 12, and 4–8 m layers at St. 8. The polychaete larvae distributed uniformly throughout the stations from surface to the 9–10 m layers, but the size and length of these larvae were larger in the lower layer than in the upper layers. Several individuals of these larvae occurred in more deeper layers where the oxygen content was so small that other animals could not survive there. Tintinnids, such as *Tintinnopsis radix*, *T. cylindrica*, *Helicostomella longa* and *Tintinnus lusus-undae* var. *tenuis* were concentrated in the maximum number at the surface layer, although they distributed downwards to 8–10 m layers. From the data given above it may be concluded that the lower limit of plankton distribution was deeper this time than in the survey of November and that the plankton animals did not inhabit in the deeper 12–12.5 m strata where the dissolved oxygen was quite absent and hydrogen sulphide was produced there. Thus the productive layer of the lagoon seems to be restricted to a thin layer between 0 and 11 meters.

General Consideration and Conclusion

1. The water is highly stagnant, and the salinity in the deeper strata is lower than in the lower strata. The dissolved oxygen content of lower strata is very small or quite absent; thus considerable amount of hydrogen sulphide is produced there almost all the year round. The mud in such area is jet black. These peculiar hydrological conditions have a great influence on the distribution of planktonic organisms; the inhabitable layers are relatively thin.

2. The components of plankton are very few. They are confined to marine organisms which are always found in the innermost part of the inlet waters, euryhaline, eurythermal and at the same time have some ability to tolerate against the changes in other physical and chemical conditions. Nevertheless no brackish water animal was found here. The pelagic fauna is rather monotonous, but the population of each species especially that of *Oithona nana* is very large. The phytoplankton is very small in quantity, and mostly consists of emigrants from Miyazu Bay (YAMAZI, unpublished); namely dinoflagellates comprising *Ceratium tripos*, *C. trichoceros*, *C. furca*, *C. fusus*, *C. lineatum*, *Pyrophacus horologicum* and other 7 neritic dinoflagellates, and diatoms comprising *Ch. peruvianus* and 14 neritic *Chaetoceros*, 6 *Rhizosolenia*, 10 neritic centralis and 7 neritic pennales. *Chaetoceros* (*Ch. affinis*, *Ch. decipiens* and *Ch. laciniosus*) in summer and *Skeletonema costatum* in winter are the most important

phytoplankters.

3. Although the constituent species are almost similar all the year round, their proportions considerably vary from time to time and from station to station. Generally the pelagic community in the lagoon is characterized by the predominance of *Oithona nana* associated with *Acartia*. *A. clausi* is a dominant copepod during spring and *A. spinicauda* is an important member from summer to autumn, although they never exceed *Oithona nana* in number.

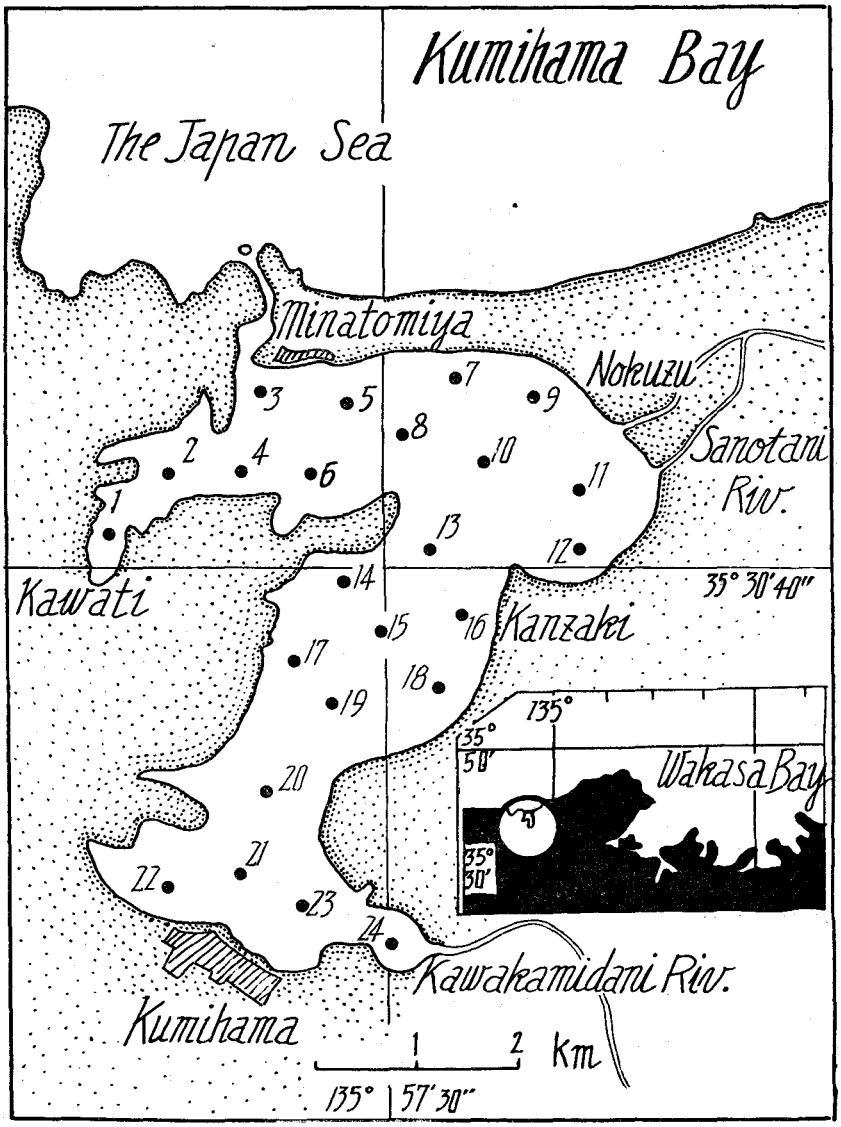

Fig. 2. Map of Kumihama Bay, showing the stations.

The larval forms are presumably produced by adult forms living in the lagoon and adapted to the peculiar environment of the lagoon. Polychaete larvae and pelecypod veligers occurred numerously. Neritic copelata *Oikopleura dioica*, chaetognath *Sagitta crassa* f. *naikaiensis* and tintinnids comprising *Tintinnopsis radix*, *Tintinnopsis tenuis*, *Favella campanula*, *Helicostomella longa*, *Tintinnus lusus-undae* var. *tenuis* and *Tin. fraknoii* are all found sparsely. *Dictyocha fibula* occurred remarkably in November, 1946.

4. The distribution of the plankton animals is limited to upper 9–11 m strata, because of the absence of dissolved oxygen and the existence of a considerable amount of hydrogen sulphide in the deeper strata forming the azoic zone. It is notewothy that a large number of abnormally large-sized larvae of benthic polychaetes were found just above this azoic zone far off the shallow coastal region. Probably they had been unable to settle on the bottom and then to grow up, because of unfavourable environment there.

KUMIHAMA BAY

General Hydrological Conditions

Kumihama Bay is about 7 sq. km in area and communicates directly with the Japan Sea through the narrow and very shallow passage, only three meter deep in the north (Fig. 2). The bay is divided into two basins: the main Kumihama basin and Kawati basin. The maximum depth of the bay is 22 meters at St. 9. The mud of the deep parts is soft and jet black in color except in Kawati basin and near the passage, where it was grayish and yellowish brown respectively.

Water temperature at the surface varied from 20.9° to 22.5°C; 21°C was recorded most widely throughout the bay, excepting the region near the passage where it was 22°C (Table 3). Vertically the temperature decreased regularly with depth (Table 4). The salinity at the surface was higher in the mouth than in the inner part of the bay, where the river water of the Sanotani flows in. Vertically salinity increased with depth. Dissolved oxygen decreased conspicuously below 6–9 meter layers to a very small amount or quite near the bottom of the deeper region; and this condition caused the lower limit of the plankton distribution as was found in Yosa-Naikai.

Plankton Community

The Plankton on June 22, 1947

The plankton constituents shown in Table 3 showed a great similarity to that of the Yosa-Naikai. The total number of plankton was larger in the central part and the neighbourhood of the passage, and the population of zooplankton was very rich as in Yosa-Naikai. The larger numbers of zooplankton were recorded at the head and the central part of the Kumihama basin. Copepods and their nauplii and cope-

podids were the most remarkable members in percentage and also in numerical abundance. The total number of copepods was larger in Kawati basin and Sts. 14, 15, 22 and 24 in the Kumihama basin than in the area comprising other stations. *Oithona nana* was predominant in wide range and varied from 0.8 to 16 thousands per 10 liters, from 75 to 90 in percentage composition in total copepods. *Paracalanus parvus* was abundant in Sts. 14, 15, 17, 23 and 24 in Kumihama basin, where it reached up to 16–48 in percentage composition in copepods. The plankton in Kumihama Bay was characterized, this time, by the dominance of *Paracalanus parvus* and diatoms and the fewness of *Acartia* and tintinnids. Ostracods, chaetognath, tunicate and larval forms were also found in the bay as in Yosa-Naikai. Most of the individuals of chaetognath and tunicate were usually in immature stages.

Vertical Distribution of Zooplankton on June 22, 1947

The vertical distribution of plankton at Sts. 9, 16 and 21 in day time is given in Table 4, where the individual numbers in 10 liters of sea water at each layer are compared one another. The total zooplankton attained to the maximum between the 3–9 meter layers except for St. 10 where the maximum was found in the 0–3 meter layers. No plankton was found at all between the 18 meter layer at St. 9 and under the 4 meter layer at St. 21. The vertical distribution of plankton was limited here also by the absence of oxygen together with the existence of hydrogen sulphide in the deeper strata.

Conclusion

1. Kumihama Bay is very like Yosa-Naikai in its isolated topography and in the distribution of water temperature, transparency, water color, salinity, oxygen and pH. The environmental conditions in both bays are by far particular as compared with bays or inlets having a rather wide mouth.

2. The plankton community of the bay is strongly affected by the stagnation caused by the isolation from the open sea as in Yosa-Naikai and Nakanoumi (MIYADI *et al*, 1954). In lower layers of the central part of the bay the oxygen content is extremely small or quite absent and the hydrogen sulphide is produced; therefore the inhabitable layer of the plankton is thinned considerably, although the upper productive stratum is somewhat thicker than in Yosa-Naikai.

3. The lower the salinity and the transparency of the water the more marine species are eliminated in the water, and contrarily the euryhaline and eurythermal species, *Oithona nana* in this case, becomes dominant, being distributed evenly in the bay and associated with *Paracalanus parvus* and *Acartia*. The offshore species brought into the bay from the open sea are too poor as in the case of Yosa-Naikai to contribute to form some characteristic communities. Several individuals of brackish water copepod *Sinocalanus tenellus* occurred in the bay, but only in the innermost

part of lower salinity; on the other hand *Paracalanus parvus* was distributed widely. These two species were not found at all in Yosa-Naikai. Thus it may be concluded safely that Yosa-Naikai is more perfectly stagnant than Kumihama Bay.

4. The constitution of zooplankton is very monotonous as in both Yosa-Naikai and Nakanoumi (MIYADI *et al*, 1954), although some species are produced very abundantly in both waters.

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TABLE 1. Distribution of important zooplankton in Yosa-Naikai. Calculated for 10 liters.

Date	June 4, 1945					Nov. 25, 1945						April 4, 1946				April 20, 1946				Nov. 1, 1946		
Station number	1	6	8	10	14	5	6	7	9	12	14	6	6–8	8	Chan.	2	8	10	12	3	6	12
Transpareney	2	2.5	3.0	2.5	2.0	2.3	2.4	2.5	2.4	2.3	2.0	2.6	2.6	2.6								
Temperature (0 m)	22.0	22.0	22.0	22.0	22.0	14.5	14.2	13.7	13.5	14.5	14.0	16.5	16.5	16.6								
Mud temperature	13.0	13.0	14.0	13.5	16.0	18.5	18.0	18.5	18.3	19.6	20.0	13.4	13.3	13.1								
Total number of zooplankton (Z)																						
Total number of phytoplankton (P)																						
Percentage of Z/Z+P																						
Percentage of P/Z+P																						
Composition of zooplankton																						
Copepods																						
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia spinicauda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	13.6	9.6	12.8	8.9	19.2	13.6	16.0	14.8	13.9	17.2	16.1	1.0	2.1	3.1	2.0	12.8	6.9	17.5	20.0	0.15	0.23	0.04
Oithona nana	69.0	74.7	68.8	63.4	58.0	49.6	67.5	69.8	66.5	75.9	77.5	63.2	60.6	56.6	53.9	68.0	83.8	51.6	21.4	0.21	0.22	0.26
Protozoans																						
Dictyocha fibula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	95.5	94.9	95.2
Tintinnopsis radix	—	—	—	—	—	—	—	—	—	—	—	3.8	4.2	2.9	3.9	—	—	—	—	1.3	1.1	1.4
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnus fraknoii	—	—	—	—	—	—	—	—	—	—	—	0.5	1.2	0.8	1.2	1.7	0.4	9.3	11.1	1.7	1.9	1.4
Helicostomella longa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Favella campanula	1.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other animals																						
Sagitta crassa f. *naikaiensis*	0.3	0.4	0.4	0.6	0.1	2.1	2.4	1.4	1.6	0.8	1.1	0.6	0.7	0.7	0.9	3.7	+	+	1.2	—	—	—
Oikopleura dioica	0.2	—	—	0.3	0.2	—	—	—	—	—	—	0.6	0.6	0.2	0.7	—	—	—	—	—	—	0.05
Evadne tergestina	2.0	—	—	—	—	—	—	—	—	—	—	0.6	1.0	1.7	—	+	+	1.4	11.4	—	—	+
Podon leuckarti	—	—	—	—	—	—	—	—	—	—	—	—	0.6	—	—	—	—	—	—	—	—	—
Penilia schmackeri	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Larval forms																						
Copepod nauplii	7.6	10.5	5.5	14.9	10.1	19.8	8.1	6.2	9.2	1.7	—	23.8	25.8	27.1	28.6	12.0	7.3	16.9	14.3	0.4	0.4	0.7
Polychaete larvae	3.7	2.1	4.3	3.0	4.2	—	—	—	—	—	—	2.4	1.5	2.9	1.5	2.6	1.4	3.1	14.3	—	—	+
Pelecypod veligers	1.9	1.8	3.1	6.5	4.4	8.0	6.0	5.8	5.8	4.4	5.3	—	—	—	2.9	—	—	—	—	—	—	—
Gastropod veligers	—	—	3.0	—	—	6.5	—	2.0	3.0	—	—	1.9	—	1.5	1.2	—	—	—	—	—	—	—

TABLE 1. (Continued)

Date	June 20, 1947																					
Station number	2		3		4		5		6		7		8		9		10		11		12	
Transpareney	3.3		3.7		3.7		3.6		3.6		3.0		4.0		3.4		2.7		2.5		2.8	
Temperature (0 m)	23.0		23.0		22.9		23.0		23.0		23.9		22.9		23.0		24.0		24.6		24.9	
Mud temperature	15.5		15.5		15.8		—		15.1		16.0		—		15.4		15.5		16.0		17.8	
Total number of zooplankton (Z)																						
Total number of phytoplankton (P)																						
Percentage of Z/Z+P																						
Percentage of P/Z+P																						
Composition of zooplankton																						
Copepods																						
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia spinicauda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	—	—	—	—	—	—	—	—	—	—	30	0.1	—	—	—	—	—	—	—	—	—	—
Oithona nana	180	12	630	6.5	2,750	37.1	2,410	24.1	690	50.0	10,350	38.3	1,830	22.2	3,070	25.0	7,280	36.0	8,260	91.4	1,080	33.8
Protozoans																						
Dictyocha fibula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnopsis radix	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinus fraknoii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicostomella longa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Favella campanula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other animals																						
S. crassa f. *naikaiensis*	+	+	—	—	—	—	—	—	+	+	—	—	+	+	—	—	—	—	—	—	—	+
Oikopleura dioica	+	0.6	+	0.1	—	—	—	—	—	—	+	0.1	+	0.1	—	—	—	—	+	0.1	—	—
Evadne tergestina	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Podon leuckarti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia schmackeri	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Larval forms																						
Copepod nauplii	1,200	80	8,860	91.5	4,640	62.4	7,560	75.6	720	53.7	15,310	57.9	6,240	75.8	9,140	74.8	13,820	61.9	640	7.0	1,860	61.0
Polychaete larvae	20	1.3	30	0.3	30	0.4	20	0.2	—	—	40	0.2	50	0.6	40	0.3	40	1.8	70	0.8	30	1.0
Pelecypod veligers	—	—	—	—	10	0.1	20	0.2	—	—	30	0.1	20	0.2	—	—	—	—	10	0.1	—	—
Gastropod veligers	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 1. (Continued)

Date	June 20, 1947										March 19, 1948													
Station number	13		14		15		16		Chan.		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Transpareney	2.5		2.4		2.5		2.5		—		4.6	4.8	4.9	4.7	5.0	5.0	4.0	4.8	4.6	3.7	3.7	3.6	3.8	3.8
Temperature (0 m)	24.4		24.5		24.8		23.4		—		11.5	10.8	10.6	9.0	10.0	9.2	8.9	9.0	9.0	8.5	8.0	7.5	7.5	7.3
Mud temperature	19.9		19.5		—		—		—		12.5	11.5	11.3	11.3	11.2	11.0	11.0	11.0	11.0	11.8	12.0	12.2	12.0	12.0
Total number of zooplankton (Z)																								
Total number of phytoplankton (P)																								
Percentage of Z/Z+P																								
Percentage of P/Z+P																								
Composition of zooplankton																								
Copepods																								
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.9	10.8	4.4	2.7	3.7	—	—	—	—
Acartia spinicauda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.7	6.7	8.6	3.5	1.5	8.7	11.6	16.4	4.1
Acartia clausi	—	—	—	—	—	—	—	—	—	—	3.5	10.8	3.8	1.2	3.4	3.7	6.7	8.6	3.5	1.5	8.7	11.6	16.4	4.1
Oithona nana	10,000	36.1	2,130	7.3	4,180	27.6	1,960	34.9	490	57.2	31.6	11.3	16.4	7.9	6.2	6.7	9.8	12.9	11.1	2.7	—	—	22.8	24.2
Protozoans																								
Dictyocha fibula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnopsis radix	—	—	—	—	—	—	—	—	—	—	0.9	11.3	7.4	8.3	18.1	19.6	14.0	28.9	46.0	80.6	25.6	34.1	8.8	8.1
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	—	1.7	1.6	—	1.2	5.1	—	3.8	2.9	3.1	0.9	—	—	3.9	4.0
Tintinnus fraknoii	—	—	—	—	—	—	—	—	—	—	28.1	19.5	16.0	65.0	21.4	6.7	10.5	9.4	10.7	1.6	18.8	—	—	9.5
Helicostomella longa	—	—	—	—	—	—	—	—	—	—	1.8	2.7	4.2	4.7	8.5	3.7	16.7	13.8	14.6	5.2	20.2	27.0	22.6	31.5
Favella campanula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other animals																								
S. crassa f. *naikaiensis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oikopleura dioica	—	—	—	—	—	—	—	—	+	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Evadne tergestina	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Podon leuckarti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia schmackeri	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Larval forms																								
Copepod nauplii	17,620	63.6	2,630	92.4	10,690	72.0	4,780	83.7	260	30.9	29.9	19.5	28.0	4.4	15.8	16.8	12.9	22.0	7.2	3.7	17.6	9.2	11.3	8.5
Polychaete larvae	60	0.2	50	0.1	20	0.1	20	0.3	20	2.0	2.6	11.3	16.2	—	21.5	19.5	14.6	—	—	2.7	8.9	18.3	10.7	—
Pelecypod veligers	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropod veligers	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14.7	—	—	—	0.2	—	—	3.8	2.0

TABLE 2. Vertical distribution of hydrological conditions and zooplankton components in Yosa-Naikai. Calculated for 10 liters.

Date	November 1, 1946																
Station number	3									6							
Depth (m)	0	1	2	3	4	5	6	7	9	0	2	3	5	6	9	10	12
Temperature (°C)																	
Salinity (‰)																	
Oxygen (cc/L)																	
Oxygen (%).																	
Total number of zooplankton	53,980	47,900	13,960	8,520	4,630	5,210	6,630	1,150	0	13,180	17,850	11,940	32,520	8,220	3,150	940	—
Total number of phytoplankton	485,820	51,320	600,870	225,230	150,000	87,900	41,500	50,200	+	121,780	157,650	99,570	391,880	52,830	36,680	8,800	+
Percentage of Z/Z+P																	
Percentage of P/Z+P																	
Composition of zooplankton																	
Copepods																	
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	80	40	30	20	50	20	—	—	—	30	10	10	50	—	10	—	—
Oithona nana ♂																	
Oithona nana ♀	110	120	160	80	70	320	190	20	—	30	90	70	300	30	20	10	—
Protozoans																	
Dictyocha fibula	51,500	46,550	12,100	7,750	1,720	2,600	4,200	1,000	—	12,500	16,550	6,380	29,350	7,500	2,800	750	—
Tintinnopsis radix	720	450	620	200	230	250	120	50	—	150	300	520	200	50	0	0	—
Tintinnus tenuis	900	200	470	170	150	180	—	—	—	250	500	600	390	100	120	0	—
Tintinnus fraknoii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicostomella longa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Favella campanula	50	100	120	30	70	80	—	—	—	—	—	200	150	60	—	—	—
Other animals																	
S. crassa f. *naikaiensis*	—	—	—	—	—	—	10	—	—	—	—	—	10	—	10	—	—
Oikopleura dioica	—	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Evadne tergestina	—	—	—	—	—	—	—	—	—	—	10	—	10	—	—	—	—
Podon leuckarti	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia schmackeri	—	—	—	—	—	—	—	—	—	—	20	10	20	—	10	—	—
Larval forms																	
Copepod nauplii and copepodids	230	280	410	130	120	170	70	—	—	50	80	130	370	30	20	20	—
Polychaete larvae	—	—	—	—	—	10	—	80	—	—	—	—	—	80	40	30	—
Pelecypod veligers	—	—	—	—	—	—	—	—	—	—	10	—	10	—	—	—	—
Gastropod veligers	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 2. (Continued)

Date	November 1, 1946						June 20, 1947									
Station number	12						2						6			
Depth (m)	0	1	3	6	10	11	0	2	4	6	10	12	0	2	4	6
Temperature (°C)							23.0		21.86	20.85	17.82	16.76	23.00	22.73	21.23	20.55
Salinity (‰)							22.99			26.91	30.70	29.90	22.79	24.33	28.71	29.00
Oxygen (cc/L)							5.87			4.86	3.19	1.69	6.09	5.93	5.38	2.91
Oxygen (%)							108.1			87.5	55.4	28.4	112.1	108.3	98.5	53.6
Total number of zooplankton	44,110	53,720	45,060	42,010	5,380	—	440	6,470	2,2170	24,000	280	—	670	2,820	13,640	12,720
Total number of phytoplankton	551,040	37,860	30,000	262,750	60,000	5,000	400	290	300	330	90	—	120	90	30	70
Percentage of Z/Z+P																
Percentage of P/Z+P																
Composition of zooplankton																
Copepods																
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	20	30	40	10	—	—	—	—	10	—	—	—	—	—	—	—
Oithona nana ♂	—	—	—	—	—	—	10	30	90	80	10	—	—	40	90	30
Oithona nana ♀	110	80	90	30	20	—	50	350	960	2,790	150	—	210	1,270	227	1,860
Protozoans																
Dictyocha fibula	42,000	47,500	30,600	30,282	4,710	—	—	—	—	—	—	—	—	—	—	—
Tintinnopsis radix	600	210	600	250	—	—	60	10	—	—	—	—	30	10	80	70
Tintinnus tenuis	600	1,500	400	300	—	—	20	10	—	—	—	—	—	—	10	—
Tintinnus fraknoii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicostomella longa	—	—	—	—	—	—	240	160	50	50	—	—	80	130	440	50
Favella campanula	—	400	100	300	—	—	—	—	—	—	—	—	—	—	—	—
Other animals																
S. crassa f. *naikaiensis*	—	—	—	—	—	—	10	20	—	—	—	—	—	10	10	—
Oikopleura dioica	20	—	—	—	—	—	10	10	10	—	—	—	—	20	10	—
Evadne tergestina	10	10	—	—	10	—	—	—	—	—	—	—	—	—	—	—
Podon leuckarti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia schmackeri	10	30	40	—	10	—	—	—	—	—	—	—	—	—	20	—
Larval formsl																
Copepod nauplii and copepodids	270	210	380	80	30	—	300	5,060	2,046	20,040	40	—	140	1,070	9,440	9,410
							100	650	460	940	20	—	100	140	1,080	1,240
Polychaete larvae	—	—	—	30	40	—	10	20	10	30	40	10	—	40	90	40
Pelecypod veliger	—	10	10	10	10	—	—	10	10	—	—	—	—	—	—	—
Gastropod veliger	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 2. (Continued)

Date	June 20, 1947															
Station number	6			8							12					
Depth (m)	8	10	12	0	2	4	6	8	10	12.5	0	2	4	6	8	9
Temperature (°C)	20.55	17.58	16.93	22.90	22.19	21.76	20.66	20.63	19.18	17.73	24.90			20.60		17.23
Salinity (‰)	29.72	30.19	30.10	22.36	24.76	27.61	28.61	29.31	30.01	29.49	21.32			28.42		29.65
Oxygen (cc/L)	2.46	1.67	1.67	5.82	5.87	5.82	5.59	4.86	3.19	1.23	6.09			5.71		2.85
Oxygen (%)	45.0	28.3	28.3	106.9	106.5	104.4	100.9	88.3	57.6	20.6	103.5			103.0		48.5
Total number of zooplankton	10,240	—	—	460	1,960	6,890	12,320	8,180	1,140	40	1,160	5,710	17,860	13,530	14,540	7,050
Total number of phytoplankton	20	—	—	170	130	120	140	90	30	0	240	290	300	270	120	110
Percentage of Z/Z+P																
Percentage of P/Z+P																
Composition of zooplankton																
Copepods																
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	—	—	—	—	—	—	—	—	—	—	10	10	—	10	10	—
Oithona nana ♂	60	—	—	0	40	60	50	80	—	—	20	40	70	50	100	50
Oithona nana ♀	3,950	—	—	100	770	1,060	210	2,180	550	—	340	1,530	340	283	7,640	2,220
Protozoans																
Dictyocha fibula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnopsis radix	—	—	—	—	20	10	20	20	—	—	10	20	10	20	10	10
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnus fraknoii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicostomella longa	30	—	—	30	50	40	50	40	20	—	20	120	20	30	10	20
Favella campanula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other animals																
S. crassa f. *naikaiensis*	—	—	—	—	—	—	10	10	—	—	—	—	—	—	—	—
Oikopleura dioica	—	—	—	—	—	10	20	10	—	—	—	30	—	—	—	—
Evadne tergestina	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Podon leuckarti	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia schmackeri	10	—	—	—	—	10	40	10	—	—	—	—	—	—	—	—
Larval forms																
Copepod nauplii and copepodids	4,940	—	—	50	700	5,080	9,830	4,930	430	—	400	2,270	12,490	8,970	3,920	3,780
	1,190	—	—	160	280	490	980	350	80	—	240	1,270	1,590	1,370	2,730	920
Polychaete larvae	20	—	—	50	40	30	30	10	20	40	10	220	40	60	40	30
Pelecypod veligers	10	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—
Gastropod veligers	30	—	—	—	—	—	—	—	—	—	—	40	20	10	—	—

TABLE 3. Distribution of zooplankton in Kumihama Bay on June 22, 1947. Calculated for 10 liters.

Station number	2	3	5	6	7	9	10	12	13	14
Depth (m)	6.5	3.2	3.0	12.5	21.0	22.0	15.0	9.0	12.5	11.4
Transparency (m)	4.9	+	+	4.5	4.2	4.8	5.0	4.5	4.4	4.1
Temperature at 0 m (°C)	22.0	21.9	21.0	21.0	20.8	22.2	22.9	21.0	20.9	21.4
Bottom texture	M	S	S	M	M	M	M	M	M	M
Total number of zooplankton (Z)	46,150	4,720	21,960	18,430	7,680	14,080	16,450	17,880	19,040	29,740
Total number of phytoplankton (P)	17,140	8,750	22,870	8,080	12,730	12,400	17,510	40,460	33,710	16,260
Percentage of Z/Z+P	72.9	36.2	48.9	69.5	37.6	63.2	48.4	30.6	36.9	64.6
Percentage of P/Z+P	27.1	63.8	51.1	30.5	62.4	36.8	51.6	69.4	64.0	35.4
Composition of zooplankton										
Copepods										
Paracalanus parvus	820	200	810	840	320	670	420	560	420	1,200
Acartia clausi	—	—	—	—	—	—	—	—	—	—
Oithona nana	7,680	750	2,020	2,640	1,370	2,020	3,390	3,200	3,120	6,020
Protozoans										
Distephanus speculum	40	20	30	10	10	30	—	20	—	—
Tintinnopsis sufflata	40	30	40	40	30	30	80	1,530	120	—
Tintinnopsis radix	20	10	20	30	10	20	20	400	70	280
Tintinnus tenuis	10	10	10	—	—	—	10	—	—	—
Helicostomella longa	80	30	120	50	40	40	60	80	60	70
Other animals										
S. crassa f. *naikaiensis*	40	10	+	+	20	40	180	100	40	20
Oikopleura dioica	50	40	60	20	40	—	100	20	80	40
Evadne tergestina	20	20	30	10	40	10	20	60	40	90
Penilia schmackeri	20	10	10	10	—	—	—	—	20	10
Podon leuckarti	30	10	50	20	10	+	20	60	20	—
Larval forms										
Oithona nana nauplii	36,480	3,050	17,660	12,720	5,020	10,410	11,620	12,250	14,250	21,440
Paracalanus nauplii	470	380	510	440	270	330	380	230	280	400
Polychaete larvae	30	10	20	30	120	20	10	10	20	20
Pelecypod veligers	70	+	20	40	50	20	10	10	30	10
Gastropod veligers	130	50	310	70	70	70	50	20	30	20

TABLE 3. (Continued)

Station number	15	16	17	19	20	21	22	23	24	Total
Depth (m)	10.0	15.0	12.9	13.0	14.0	6.0	4.3	5.0	3.0	
Transparency (m)	4.3	4.4	4.1	4.3	4.3	3.5	3.3	3.8	2.9	
Temperature at 0 m (°C)	21.1	21.9	21.0	21.0	21.2	22.5	21.2	21.0	21.0	
Bottom texture	M	M	M	M	M	M	M	M	M	
Total number of zooplankton (Z)	42,710	7,340	9,390	8,970	8,100	7,680	8,280	47,590	4,720	423,240
Total number of phytoplankton (P)	32,670	16,970	9,440	9,160	11,330	18,210	2,662	44,070	63,880	879,560
Percentage of Z/Z+P	56.6	30.2	49.8	49.4	41.7	29.6	75.6	50.2	7.1	51.9
Percentage of P/Z+P	43.4	69.8	50.2	50.6	58.3	70.4	24.4	49.8	92.9	48.1
Composition of zooplankton										
Copepods										
Paracalanus parvus	1,680	230	960	320	150	80	600	920	980	1,290
Acartia clausi	—	—	—	—	—	—	90	40	30	160
Oithona nana	9,160	680	1,050	2,210	1,280	270	16,250	4,260	2,820	71,460
Protozoans										
Distephanus speculum	—	—	—	—	—	—	—	—	—	160
Tintinnopsis sufflata	20	10	30	10	30	—	60	80	90	2,260
Tintinnopsis. radix	180	30	40	50	50	70	330	250	2,940	4,820
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	40
Helicostomella longa	30	40	—	—	—	30	140	180	—	1,050
Other animals										
S. crassa f. *naikaiensis*	30	+	+	10	20	+	20	10	+	560
Oikopleura dioica	30	10	—	20	40	50	60	40	60	700
Evadne tergestina	20	40	20	10	40	+	10	—	+	450
Penilia schmackeri	10	10	—	10	10	10	20	20	—	160
Podon leuckarti	—	—	—	—	—	10	—	10	—	240
Larval forms										
Oithona nana nauplii	30,550	6,010	6,210	6,010	6,080	6,820	61,880	40,530	38,670	348,620
Paracalanus nauplii	670	190	1,000	130	200	280	3,170	880	1,610	12,030
Polychaete larve	20	10	100	40	20	—	40	30	—	550
Pelecypod veliger	30	40	10	30	10	—	40	50	—	450
Gastropod veliger	40	+	20	30	100	—	20	20	—	1,040

TABLE 4. Vertical distribution of hydrological conditions and zooplankton components in Kumihama Bay on June 22, 1947. Calculated for 10 liters.

Station number	9								16						21			
Depth (m)	0	3	6	9	12	15	18	21	0	3	6	9	12	14	0	3	4	5.5
Temperature (°C)	21.9	21.21	18.55	18.74	18.37	18.49	18.30		21.90	21.76	17.75	18.11	18.18	18.15	22.50	22.45	19.42	18.00
Salinity (‰)	20.33	28.13	30.25	30.73	31.20	34.43	34.72		—	32.77	33.53	34.13	34.23	34.43	22.56	29.19	32.61	32.74
Oxygen (cc/L)	6.03	5.44	3.17	3.15	2.44	1.14	2.67		6.08	5.32	2.17	2.15	1.78	1.88	6.27	6.09	2.28	1.71
Oxygen (%)	110.5	99.0	55.8	53.5	37.6	20.6	48.2		—	100.7	38.7	38.5	32.1	33.8	112.7	112.6	41.1	32.6
Total number of zoo-	16,350	8,330	6,610	5,780	1,860	650	—	—	741	2,972	3,186	3,576	148	97	756	2,306	—	—
Total number of phyto-	17,510	16,240	9,670	4,280	570	370	—	—	1,697	1,327	348	170	77	0	1,821	1,088	—	—
Percentage of Z/Z+P	48.2	33.9	40.6	57.4	76.5	63.7	—	—	30.4	69.2	90.1	95.4	65.7	100	41.5	67.9	—	—
Percentage of P/Z+P																		
Composition of zoo-																		
Copepods																		
Paracalanus parvus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	420	160	120	70	60	20	—	—	230	420	420	560	70	—	80	100	—	—
Oithona nana	3,390	1,240	1,170	1,960	480	120	—	—	680	3,570	3,620	2,940	530	280	280	2,610	—	—
Protozoans																		
Distephanus speculum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnopsis sufflata	80	—	20	20	—	—	—	—	30	70	50	20	10	—	70	20	—	—
Tintinnopsis radix	20	10	10	80	19	—	—	—	10	40	60	30	10	—	—	—	—	—
Tintinnus tenuis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helicostomella longa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other amimals																		
S. crassa f. *naikai-ensis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oikopleura dioica	100	20	—	—	—	—	—	—	10	20	—	20	—	—	10	20	—	—
Evadne tergestine	—	60	10	10	—	—	—	—	20	10	40	—	—	—	—	80	—	—
Penilia schmackeri	+	40	40	10	—	—	—	—	—	10	10	—	—	—	—	—	—	—
Podon leuckarti	20	10	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—	—
Larval forms																		
Oithona nauplii	6,550	3,720	3,100	1,580	840	70	—	—	5,320	20,350	21,400	27,600	220	350	5,600	17,120	—	—
Oithona copepodids	5,070	2,510	1,630	1,800	290	150	—	—	690	4,520	5,380	3,520	80	260	1,220	2,730	—	—
Paracalanus nauplii	110	120	100	20	20	—	—	—	80	180	210	220	40	—	60	70	—	—
P. copepodids	120	140	80	30	10	—	—	—	110	290	290	300	20	—	230	160	—	—
Polychaete larvae	10	40	30	+	10	40	—	—	10	40	40	20	60	40	—	20	—	—
Pelecypod veligers	10	+	+	10	10	20	—	—	40	+	+	20	—	—	—	—	—	—
Gastropod veligers	50	10	30	10	40	160	—	—	20	+	+	40	410	—	—	40	—	—